

EFFECTIVENESS OF THORAX & PELVIS SIDE AIRBAG FOR IMPROVED SIDE-IMPACT PROTECTION

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ABSTRACT

In recent years, side-impact crashes in the US between SUVs (Sports Utility Vehicle) or LTVs (Light Trucks & Vans) and passenger cars are increasing, resulting in a high number of serious or fatal injuries. It has become an important task to reduce body injury levels, not only to the head, but to the thorax and pelvis as well. One way to protect the occupant's thorax and pelvis in side-impact crash is T&P SAB (Thorax & Pelvis Side Airbag).

This research paper will show a reduction of injury levels as a result of T&P SAB, using IIHS (Insurance Institute for Highway Safety) SUV side-impact crash conditions in MADYMO simulation and sled test results. Furthermore, analyses of the pelvis area were conducted using THUMS Simulation. It was confirmed that T&P SAB has the potential to protect the occupant's thorax and pelvis during side-impact crash, as well as reduce the level of injury.

THUMS (Total Human Model for Safety)

FEM Human model, created by Toyota Central R&D Labs

INTRODUCTION

Within the last 2 decades in the US, the number of side-impact crashes involving SUV/LTVs to passenger cars has increased remarkably. According to FARS (Fatal Analysis Reporting System) data, comparing the fatality rate by side crash type, between 1980-81 to 2000-01 the fatality rate of SUV/LTV vs car increased from 29% to 57%. The fatalities reported for passenger car vs passenger car decreased from 71% to 43%(Table 1).

According to NASS (National Automotive Sampling System) Crashworthiness Data, the body parts inflicted with the highest injury levels (higher than AIS3) during side crash were thorax 61% and pelvis 35%, these ratios being higher than head injury level 31% (Table 2).

Table 1.

Percent of driver death in 1-3-year-old passenger vehicle struck on the driver side by another passenger vehicle, by type of striking vehicle

STRIKING VEHICLE	STRUCK VEHICLE	CALENDAR YEARS		
		1980-81	1990-91	2000-01
Car	Car	71%	61%	43%
SUV or pickup	Car	29%	39%	57%
Car	All passenger vehicles	70%	60%	43%
SUV or pickup	All passenger vehicles	30%	40%	57%

Source: Fatality Analysis Reporting System, National Highway Traffic Safety Administration

Source : NHTSA STATUS REPORT (Vol.38, No.7 June 28,2003)

Table 2.

Distribution of serious and fatal injuries, by body region, to drivers of passenger vehicles struck on the driver side, calendar years 1997-2001

BODY REGION	MALE	FEMALE	TOTAL
Head, face, or neck	29%	34%	31%
Thorax	66%	51%	61%
Abdomen	14%	13%	13%
Upper extremities	15%	18%	16%
Pelvis & lower extremities	33%	38%	35%
Spine	5%	2%	4%

Notes: Serious injuries are AIS (Abbreviated Injury Scale) 3 or greater. Drivers frequently suffer AIS 3+ injuries to multiple body regions.

Source: National Automotive Sampling System/Crashworthiness Data System, National Highway Traffic Safety Administration

Source : NHTSA STATUS REPORT (Vol.38, No.7 June 28,2003)

CIREN (Crash Injury Research & Engineering Network) reported, during a public meeting that it is

important to reduce injury level of thorax and pelvis because those parts are at highest risk of getting injured by the door panel in a side-impact crash.

One way to protect the occupant's thorax and pelvis during a side-impact crash is utilization of T&P SAB. Adding a Curtain Airbag to protect the head during a crash (in combination with T&P SAB) can further reduce full side body injury levels. In this research, it is perceived that injury levels decrease as an effect of using T&P SAB in the condition of IIHS SUV side-impact testing by using MADYMO Simulation and Sled Testing. A more detailed analysis of the pelvis area was conducted using THUMS Simulation.

Evaluation Method

This research consists of MADYMO Simulation and Sled Testing, with the behavior of the door derived from the result of IIHS SUV side-impact testing.

MADYMO Simulation

MADYMO Simulation was used to measure the relationship between injury level of thorax and pelvis of occupant and design of T&P SAB (configuration, dimensions, etc.). Shown in Figure 1, T&P cushion was divided into 3 parts. 3 levels of bag size and inner pressure were set for each of the 3 parts. Rib Deflection and Iliac Force were evaluated (the average of the 5 ribs was reported) using a Morris Quadratic Design DOE that consisted of 78 simulations (Table 3). The result can be seen in Figures 2, 3 and 4.0

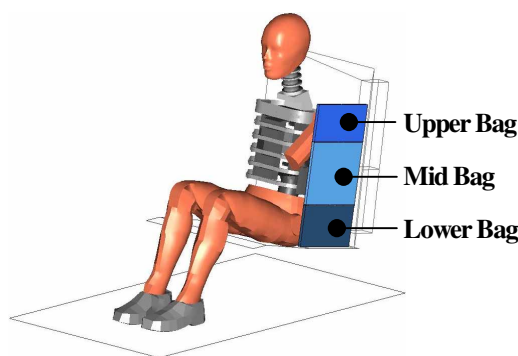


Figure 1. MADYMO Simulation model

Table 3.
Simulation matrix

Case	Upper Airbag Length	Upper Airbag Thickness	Upper Airbag Pressure	Mid Airbag Length	Mid Airbag Thickness	Mid Airbag Pressure	Lower Airbag Length	Lower Airbag Thickness	Lower Airbag Pressure
1	A1	B1	C1	D1	E1	F1	G1	H1	I1
2	A1	B2	C1	D1	E2	F1	G1	H2	I1
3	A1	B1	C1	D1	E1	F2	G1	H1	I1
4	A1	B1	C1	D1	E1	F1	G1	H1	I2
5	A1	B1	C1	D1	E1	F1	G1	H1	I3
6	A1	B2	C1	D1	E2	F1	G1	H2	I1
7	A1	B1	C1	D1	E2	F1	G1	H1	I2
8	A1	B1	C1	D1	E1	F2	G1	H1	I1
9	A1	B1	C1	D1	E1	F1	G1	H1	I3
10	A1	B2	C1	D1	E2	F1	G1	H2	I1
11	A1	B1	C1	D1	E2	F1	G1	H1	I2
12	A1	B1	C1	D1	E1	F2	G1	H1	I1
13	A1	B2	C1	D1	E1	F1	G1	H2	I1
14	A1	B2	C1	D1	E2	F1	G1	H2	I1
15	A1	B1	C1	D1	E1	F2	G1	H1	I2
16	A1	B1	C1	D1	E1	F1	G1	H1	I3
17	A1	B2	C1	D1	E2	F2	G1	H2	I1
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19	A1	B1	C1	D1	E2	F1	G1	H1	I2
20	A1	B1	C1	D1	E1	F2	G1	H1	I1
21	A1	B1	C1	D1	E2	F2	G1	H1	I1
22	A1	B2	C1	D1	E2	F2	G1	H2	I1
23	A1	B1	C1	D1	E1	F1	G1	H1	I3
24	A1	B1	C1	D1	E2	F1	G1	H1	I2
25	A1	B2	C1	D1	E1	F2	G1	H2	I1
26	A1	B2	C1	D1	E2	F2	G1	H2	I1
27	A1	B1	C1	D1	E2	F2	G1	H1	I2
28	A1	B1	C1	D1	E1	F2	G1	H1	I1
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66	A1	B2	C1	D1	E2	F2	G1	H2	I1
67	A1	B2	C1	D1	E2	F2	G1	H2	I1
68	A1	B2	C1	D1	E2	F2	G1	H2	I1
69	A1	B1	C1	D1	E2	F2	G1	H1	I2
70	A1	B1	C1	D1	E2	F2	G1	H1	I1
71	A1	B2	C1	D1	E2	F2	G1	H2	I1
72	A1	B1	C1	D1	E2	F1	G1	H1	I2
73	A1	B1	C1	D1	E2	F2	G1	H1	I1
74	A1	B2	C1	D1	E2	F2	G1	H2	I1
75	A1	B1	C1	D1	E2	F2	G1	H1	I2
76	A1	B2	C1	D1	E2	F2	G1	H2	I1
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78	A1	B2	C1	D1	E2	F2	G1	H2	I1

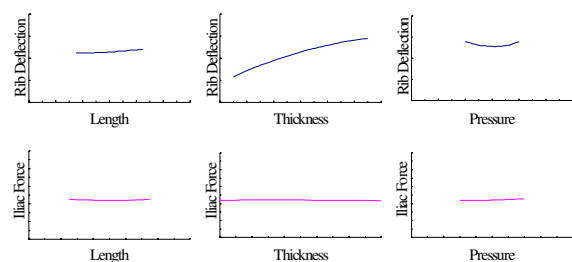


Figure 2. Effect of Upper Bag

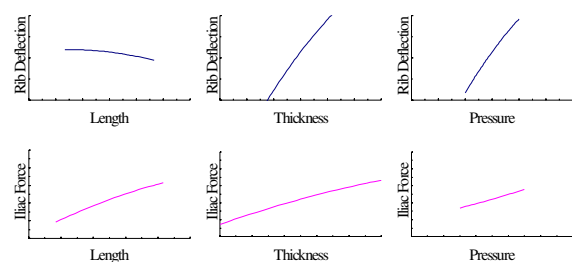


Figure 3. Effect of Mid Bag

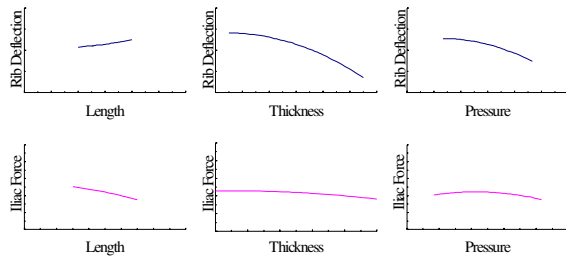


Figure 4. Effect of Lower Bag

The simulation showed that the best condition was large size and high inner pressure for Lower Bag. The injury level of thorax and pelvis for this design was lower than without SAB injury level (Figure 5).

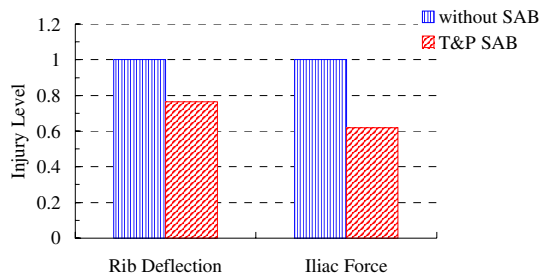


Figure 5. Simulation result of the best T&P design vs condition without SAB

With this result, it was confirmed that the T&P SAB is an effective way to protect occupants' thorax and pelvis in a side-impact crash.

Sled Test

Sled testing was conducted with and without T&P SAB. The T&P SAB sample for this test was made on the basis of best solution obtained from the MADYMO Simulation. Sled testing results were similar to simulation results, showing reduced thorax and pelvis injuries (Figure 6).

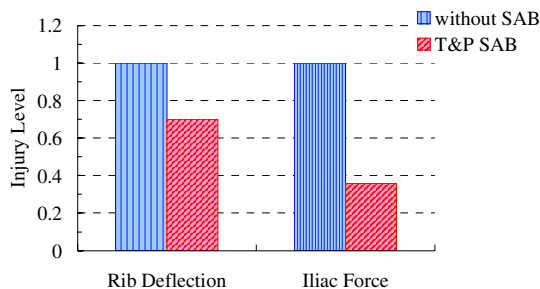


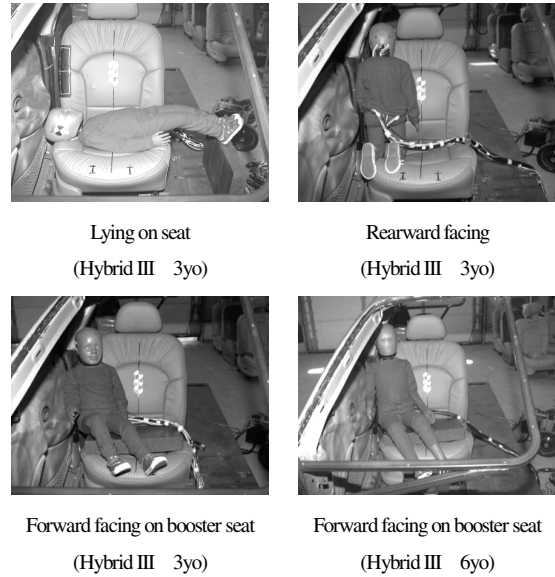
Figure 6. Sled Test Results

Out-of-Position Test

Out-of-Position (OOP) Testing was next conducted using the best design sample from simulation. Four test conditions using child dummy, recommended by TWG, were selected for OOP testing (Figure 7).

TWG (The Side Airbag Out-of-Position injury Technical Working Group)

A joint project of Alliance, AIAM, AORC, and IIHS



Source : Recommended Procedures for Evaluating Occupant Injury Risk from Deploying Side Airbags

(First Revision - July 2003)

Figure 7. Out-of-Position Test Condition

All results gained by Out-of-Position testing showed injury levels less than IARV (Injury Assessment Reference Values).

From this, T&P SAB design was optimized based on OOP performance and restraint performance.

THUMS Simulation

The Human model, such as THUMS, is a very useful tool to analyze the effect of car crashes on human body parts. THUMS simulation was used to predict the effectiveness of airbags in the field, and contributed to the development of a higher performance SAB system.



Figure 8. THUMS human model



Figure 9. THUMS Simulation model

The effect of the T&P SAB was analyzed in more detail for the occupant pelvis using THUMS simulation. As a result, it was confirmed that T&P SAB can reduce the concentrated level of forces to the pelvis. The stress distribution is shown in Figure 10.

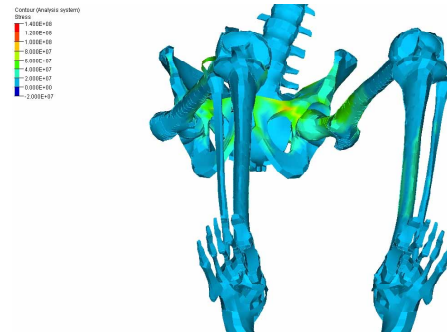


Figure 10. THUMS Simulation Results
(Stress distribution of the pelvis)

From the THUMS results, it was shown that T&P SAB can protect a wide area of the pelvis. It is one very effective way to reduce injury to the pelvis.

CONCLUSIONS

In this research, by utilizing simulation and sled testing, using IIHS SUV side-impact crash test conditions, it was confirmed that T&P SAB has the potential to protect both thorax and pelvis areas of occupant, and also reduce injury levels.

THUMS Simulation is a useful tool as it enables a more detailed analysis of the effect which is inflicted on a human body during a car accident. It can predict injury levels in the field, as well as define a clear mechanism of injuries, and help develop safer systems. We will continue to use THUMS simulation for future investigations.

REFERENCES

- [1] NHTSA
STATUS REPORT (Vol.38, No.7 June 28,2003)
- [2] TNO Automotive
MADYMO 6.2 Theory Manual
- [3] TWG (The Side Airbag Out-of-Position injury
Technical Working Group)
*RECOMMENDED PROCEDURES FOR
EVALUATING OCCUPANT INJURY RISK
FROM DEPLOYING SIDE AIRBAGS (First
Revision - July 2003)*
- [4] LSTC
LS-DYNA User's Manual
- [5] Toyota Central R&D Labs
THUMS User's Manual
- [6] Fuminori Oshita, Kiyoshi Omori, Yuko Nakahira,
Kazuo Miki
*Development of a finite element model of the
human body (7th International LS-DYNA User's
Conference)*